# DESIGN AND DETAILS OF A REINFORCED CONCRETE HARBOR LIGHT HOUSE

BY

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Armour Institute of Technology

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DESIGN and DETAILS

of a

REINFORCED CONCRETE

HARBOR LIGHT HOUSE- -

A Thesis presented by

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to the

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SPECIFICATIONS.

For A Reinforced Concrete Harbor Light-House.

Article I.

Section I/ General description of work.

The work will consist of furnishing all materials and labor required to build and erect, at the proposed site, in accordance with the following specifications and the accompanying plans, and under the direction of an engineer appointed by the party of the first part, a reinforced concrete harbor light-house.

Section II. Inspection.

The engineer shall have the right to inspect or to cause to be inspected all materials and labor furnished by the contractor. He shall reject at his discretion any material or piece of workmanship which is not in accordance with these specifications.

Section III. Workmanship.

All workmanship shall be first-class and in accordance with the directions given by the engineer.

Section IV. Cement.

All cement used shall be Portland Cement. It shall be tested by the engineer. It shall be sound, free from all lumps which cannot be readily crushed between the fingers. Its specific gravity shall be not less than 3.10 Briquettes of neat cement, after one hour in water and twenty three (23) hours in air shall show a tensile strength of not less than one hundred seventy pounds per square inch. After one day in water and six days in air they shall show a tensile strength of not less than four hundred fifty (450) pounds per square inch.

Section V. Sand.

All sand used in concrete shall be coarse, clean and sharp.

Section VI. Stone.

All stone used in concrete shall be crushed limestone. The stones shall be as nearly cubical in shape as possible. No stone used in the foundations, up to elevation plus twenty ( 20) shall be in its greatest dimension too large to pass through a ring two (2) inches in diameter, unless expressly permitted by the engineer.

No stone used in the walls or in floors above elevation plus twenty ( 20) shall be in its greatest dimensions too large

to pass through a one (1) inch ring. All stone used shall be "crusher run", with the pieces of a larger size than as above specified, screened out.

Section VII. Concrete.

Concrete, where possible, shall be mixed by a mechanical mixer of a type approved by the engineer, or where mixing is done by hand, a method shall be used which will, in the opinion of the engineer, produce results equally good as those produced by the mechanical mixer. No retempering will be allowed. When the work of depositing the concrete is suspended temporarily the surface shall be left rough. Before beginning anew to place concrete the surface of the concrete shall be thoroughly swept off and wet.

Section VIII. Reinforcement.

All reinforcement excepting that in the roof of the keeper's house shall consist of corrugated bars, of the dimensions shown on the plans, of square section. These bars shall be of medium steel, having a tensile strength not less than sixty thousand (60,000) pounds per square inch and an elastic limit not less than one half of the ultimate strength. They shall bend with one hundred and eighty (180) degrees on a radius equal to their own thickness. The reinforcement in the roof of the keeper's shouse shall be of the style known as "Trussit reinforcement".

Section IX. Timber.

All lumber used shall be straight, sound, free from wind shakes, loose of decayed knots, or other defects which may, in the opinion of the engineer, be detrimental to the rapid progress and successful completion of the work.

Article II.

THE FOUNDATIONS.

Section I. General description.

The foundations shall consist of a timber crib enclosing a solid concrete pier extending from elevation minus twenty-five (-25) to elevation plus twenty ( 20) and resting upon four concrete columns which shall in turn be supported by the bed rock.

Section II. Crib.

The timber crib shall be built on shore according to the dimensions shown on the drawings, and of the materials, and in the manner hereinafter specified. As soon after the completion of the crib as the weather conditions will permit, it shall be floated in place and moored to four stout clumps of piles.

placed as directed by the engineer. Concrete shall then be deposited on the floor of the crib, as rapidly as possible, care being taken that the crib sink evenly, until all six sides of the cutting edge rest upon the bottom of the lake. Air shall then be pumped into the working chamber until the water recedes. Struts shall then be placed under the floor as shown in the plans and excavation shall proceed until the cutting edge has reached elevation minus twenty five and five tenths (-25.5). As soon as the struts are in place, concrete will be deposited in the upper part of the crib until its top is at elevation Zero (0). This concrete shall be deposited as expeditiously as is consistent with the allowance of sufficient head room in the working chamber for the men to work to advantage. When the cutting edge has reached elevation minus twenty five and five tenths (-25.5) the excavation for the lower caissons shall be begun. No excavation shall be done in any well until all the wells previously dug have been filled with concrete up to elevation, minus twenty five (-25).

Section III. Sheathing.

The Sheathing forming the outer wall of the crib shall be of white oak, of the quality described in Article One, Section Nine, of these specifications. It shall consist of three four by twelve inch (4" x 12") planks surfaced on four (4) sides, making a wall twelve inches thick on each side of the crib, extending from the cutting edge to elevation plus five ( 5). These planks shall be firmly spiked together in the form known as Wakefield sheathing, i.e. the edge of the middle plank shall be at a distance from the edges of the side planks, equal to one half (1/2) the width of each plank. When three planks have been spiked together in the manner above described, they shall be tightly fitted and spiked to the set below and fastened by means of drift bolts to the uprights at the corners and at the middle of each side.

Section IV. Uprights & Interior Bracing.

All uprights and interior bracing shall be of the quality described in Article I. Section Nine of these specifications. They shall be accurately fitted and firmly fastened by drift bolts as shown on the plans.

Section V. Spikes.

Spikes used in the sheating shall be boat spikes of the best quality eleven inches (11") long. They shall in all cases be driven from the inside of the crib. They shall be not more than eighteen (18") inches apart on a line parallel with the edge of the planks and staggered.

Section VI. Drift Bolts.

All drift bolts shall be of a good quality of soft steel, five eights (5/8) of an inch in diameter. They shall be driven

into holes made with an auger nine sixteenths (9/16) of an inch in diameter. They shall be used to connect the sheathing and rangers to the uprights and at all joints in the interior bracing. Where drift bolts are used to connect sheathing with rangers, holes shall be bored from the inner side of the ranger to a point within one (1) inch of the outer side of the sheathing. The drift bolt shall then be driven well home into these holes. At all other points the drift bolt shall penetrate through the entire thickness of the timbers to be fastened together and, where there is room, shallproject and be bent over against the side of the timber.

Section VII. Roof of working chamber.

The roof of the working chamber shall be of reinforced concrete three feet three inches (3' 3") in depth. It will be built as shown in the plans and in accordance with the specifications for concrete in Article One, Section Seven and Eight. It shall be firmly tamped. The top surface shall be left rough. It shall be given at least one month to set before the crib is floated in place.

Section VIII. Rings in lower caissons.

The rings in the lower caissons shall be of the best quality medium steel having a tensile strength not less than sixty thousand (60,000) pounds per square inch and a modulus of elasticity not less than half of the ultimate strength. They shall be accurately centered and shaped in the form of a circle and care shallbe taken in hauling them so that they may not be sprung out of shape. Any rings or parts of rings which the engineer may reject shall be immediately set aside and removed at the earliest opportunity from the site of the work.

Section IX. Lagging in lower caissons.

The lagging to be used in the lower caissons shall be of hardwood three by six inches (3" x 6") in section, surfaced on two sides and matched. Any knot extending the entire width of the piece shall cause its immediate rejection. No set of lagging shall be of greater length than four (4) feet excepting by special permission of the engineer. There shall be at least two )2) steel rings used to brace each set of lagging.

Section X. Lock shafts.

The lock shafts shall be of riveted steel pipe with flanges as shown on the drawings. A gasket of good quality of rubber shall be used at each pair of flanges. These flanges shall be tightly bolted together and an iron washer shall be provided with each bolt. Care shall be taken to insure a tight fit between the trap door of each lock and the floor above it.

Section XI. The tie rods in upper part of crib.

The tie rods shall consist of medium steel dock rods one and one quarter (1 1/4) inches in diameter. They shall be placed as shown on the plans. They shall be provided with button heads, nuts and washers. The holes, in the timber, through which they pass shall be bored with an auger of the same diameter as the rod.

Article III.

The Keeper's House.

Section I. General description.

The keeper's dwelling shall rest directly on the foundations. It shall conform in all respects to the dimensions shown on the drawings.

Section II. Walls.

All walls shall be of concrete of the quality described in Article I. Section III. of these specification. Both interior and exterior walls shall have a facing of grout one-half (1/2) inch in thickness on both sides. The grout shall be a mixture of one part cement to two parts sand.

Section III. Doors.

The outer door shall be of a good quality of sheet steel, built up as shown in the drawings.

Section IV. Windows.

All windows shall be of a good quality of plate glass of double thickness.

Section V. Window frames and sash.

All window frames and sash shall be of heavy, pressed galvanized iron, built up according to the dimensions and in the manner shown on the drawings.

Section VI. Floors.

The tower floor shall be of moorish tile laid on the concrete foundation. The floor of the store room shall be of reinforced concrete. It shall rest on the walls of the house and of the tower. Two I - Beams shall also be used as shown in the drawings.

Section VII. The Roof.

The roof of the dwelling house shall be of reinforced concrete. The reinforcement shall be of the trussit type and

shall conform to the specifications of the "General Reinforcement Company" for that type of reinforcement.

## Article IV.

## The Tower.

### Section I. General Description.

The tower shall rest directly on the foundations and shall be firmly anchored thereto by steel rods as shown on the drawings. The wall shall be of rinforced concrete with at least one half (1/2) inch facing of grout.

### Section II. Tower Stairway.

The steps of the stairway shall be of cast iron with the upper sides corrugated. These steps shall rest upon iron risers and shall be firmly fastened to them as shown on the drawings. These risers shall be cast with collars which fit around the main steel column.

### Section III. Railing.

The stairs shall be provided with a railing which shall be of one (1) inch cast iron pipe supported on brackets, anchored to the walls by means of anchor bolts embedded in the concrete while the walls are being built.

### Section IV. Main Column.

The main column shall be a circular steel shell, built up in sections of the dimensions shown in the plans. The joints in this column shall be made by means of flanges and these flanges shall be securely bolted together.

### Section V. Window Frames.

All window frames and sash shall be of the best quality heavy pressed galvanized iron.

### Section VI. Watch room floor.

The watch room floor shall be of reinforced concrete conforming in quality to the descriptions given in Article I of these specifications. The floor shall be covered with a good quality of Moorish tile. It shall be supported by the tower wall and by six brackets of reinforced concrete as shown.

### Section VII. Watch room Port-holes.

The port holes in the watch room shall be of plate glass They shall be framed with brass and hinged at the sides in order to be opened.

Section VIII. Watch room stairs.

The steps shall consist of corrugated steel plates connected by angle irons to steel plates bent in the form of a helix. All shall be accurately fitted as shown on the drawings.

Section IX. Railings.

The railings and uprights shall be of brass tubing, bent and accurately fitted as shown on the drawings.

Section X. Lantern Room Floor.

The lantern room floor shall be of plain concrete floor resting on steel I Beams which are, in turn, supported by the watch room wall. The concrete shall conform to the description given in Article I. Section III. of these specifications, and care shall be taken to place the I Beams in their proper location as shown on the drawings.

Section XI. Glass in lantern room.

All glass shall be of the best quality plate glass of double thickness, bent accurately to the radius shown on the drawings. It shall be fastened by a suitable clasp to the frames.

Section XII. Frames in lantern room.

The frames for the glass in the lantern room shall consist of T Bars. These T Bars shall be embedded in the concrete wall and shall extend through into the lantern room floor.

Section XIII. Railings.

The railings on the balcony of the lantern room shall be of wrought iron pipe of a good quality, bent to the proper form and supported on wrought iron uprights, imbedded in the concrete floor.

Section XIV. Flue above lantern.

The flue above the lantern shall be of a good quality, galvanized iron, extra heavy and securely built as shown on the drawings.

Section XV. Lantern room roof.

The roof of the lantern room shall be of steel plate. Sections of the roof shall be bent to the shape shown on the drawings and riv ted together before the roof is raised above the floor of the lantern room.

## Section XVI. Fittings above roof.

All fittings above the roof shall be of a good quality of gray iron, accurately cast as shown on the drawings.

COMPUTATIONS.

for

REINFORCED CONCRETE

HARBOR LIGHT-HOUSE.

Cast iron weighs 470#/ cu. ft. = .27#/ cu. in.

Weights.

Weight of spire = $\frac{\pi \times 2 \times 2}{4 \times 1728} \times 24 + \frac{\pi \times 1^2}{4 \times 1728} \times 2.5 = 5.661^{\#}$

Weight of collar above sphere = $\frac{\left[\frac{\pi \times 2^2}{4} - \frac{\pi \times 1^2}{4}\right] \times 2 \times 470}{1728} = 1.28^{\#}$

Weight of sphere = $\frac{4\pi}{8}\left[10^3 - 4.625^3\right] \times .27 = 125^{\#}$

Collarbelow sphere = $3.142\left[5^2 - 4.625^2\right] \times 3 \times .27 = 9.186^{\#}$

Weight of pedestal

Taking sections $1\frac{1}{2}''$ apart diam. [illegible] $9\frac{1}{4}'', 13\frac{1}{2}'', 7\frac{1}{4}'', 8\frac{3}{4}'', 9\frac{3}{4}'', 14'', 23'', 24''$

Weight of pedestal = $\frac{.7854\left[9.25^2 - 8.5^2\right] + .7854\left(13.5^2 - 12.75^2\right)}{2} \times 1.5 \times .27$

$+ \frac{.7854\left(13.5^2 - 12.75^2\right) + .7854\left(9.25^2 - 8.5^2\right)}{2} \times 1.5 \times .27 + \frac{.27\left(9.25^2 - 8.5^2 + 8.75^2 - 8.00^2\right)}{2} \times .7854 \times 1.5$

$+ .7854 \times 1.5 \times .27 \times \frac{8.75^2 - 8.00^2 + 9.75^2 - 9.00^2 + 9.75^2 - 9.00^2 + 14.00^2 - 13.25^2}{2}$

$+ .7854 \times 1.5 \times .27 \times \frac{14.00^2 - 13.25^2 + 23.00^2 - 22.25^2 + 14.00^2 - 13.25^2 + 23.00^2 - 22.25^2}{2}$

$+ .7854 \times 1.5 \times .27 \times \frac{23.00^2 - 22.25^2 + 24.00^2 - 23.25^2}{2} + \frac{.7854 \times 3 \times .27 \times \left(24^2 - 18^2\right)}{8}$

$+ .7854 \times 11.25 \times .27 \times \left(9.25^2 - 8.5^2\right) = 95.98^{\#}$

Weight of cover-plate.

Circumference of base of cone = $2 \times 57 \times 3.142 = 358''$

Circumference of circle into which would be developed = $2 \times 72.31 \times 3.1416 = 454.4''$

Slant height of cone with plate taken out = $\sqrt{8.00^2 + 12.00^2} = 14.5$

Weight of plate = $\frac{358}{454} \times 3.142\left(72.31^2 - 14.5^2\right) \times \frac{3}{8} \times .281 = 1066^{\#}$

Total weight acting on plate = $5.661 + 1.283 + 125 + 9.186 + 95.98 + 1066 = 1310^{\#}$

$\angle$ plate makes with vertical = $\tan^{-1}\frac{57}{38} = 56°19'$

Stress in plate = $\frac{1310}{\cos 56°19'} = 2365$

Horizontal component = $2365 \sin 56°19' = 1965^{\#}$

Weight of window and sash = $(6.7[illegible] \times 2.5833 \times .0208 \times 10 \times 186) + 100 = 720^{\#}$

Diameter of circle furnishing reaction = $8'-6''$

Circumference = $26.7036' = 320''$

Stress per" = $\frac{1965}{320} = 6.2^{\#}$

Total tearing stress due to steady load = $6.2 \times 8.5 \times 12 = 632.4^{\#}$

Assume f at 12000 # per sq. in. in order to allow for wind stresses.

As

Assume $\frac{3}{8}$" plat

$$632.4 = 12000 \times \frac{3}{8} L$$

$$L = .07055^{\#}$$

Weight of T's.
10-10½' T's. @ 3.7#/ft. = 195#
Weight of all acting on floor excepting lantern = 2220#

Lantern Room Floor.

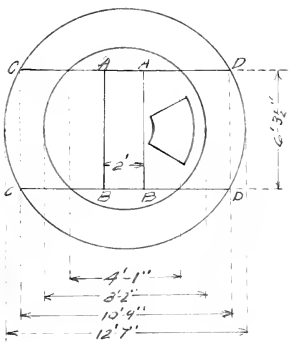
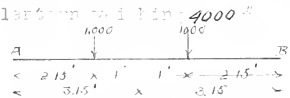



Fig I

Assume [illegible] of floor sections resting on CD. then AB support only then lantern weighing 4000#




Bending moment = (4.5-2) x 1000 x 12 = 28800
$f_s$ = 13000#/□"
Z = 1.48
Use a 4" 7½# I Beam where Z = 3

Then assume floor 8" thick

Length of outside arc of hole for [illegible] = 4'

Length of inside arc = x
$\frac{x}{4} = \frac{1.5}{3.5}$; x = 1.71'

Area of hole = difference in area between △ OFF & OGH = A
$A = \frac{(4 \times 3.5) - (3 \times 1.71)}{2} = 5.12$ □'

Weight of floor = ([3.142 x 6.29²] - 5.12) x $\frac{8}{12}$ x 1[illegible] = 1900'

Since part of this load goes directly to the wall, it will be safe to consider the total floor load evenly distributed over the beams CD

Concentrated load from lantern = 1000# at each I beam AB.

Concentrated load above, including roof = 355#

$Rc = \frac{11900}{2\times2} + 555 + 1000 = 4553^{\#}$

$Max. M = 12\left[(4553\times5.45) - (550\times5.45\times\frac{5.45}{2}) - (555\times2.05) - (1000\times1)\right]$

Max. M. = 174180 in. lbs.

$Z = \frac{174180}{13000} = 13.4$

Use an 8"-18# I beam

Weight of railing around lamp

Length of railing = 37.6992'

$1\frac{1}{2}$" Wrought iron pipe weighs 2.68#/ft.

6. railing posts of $1\frac{1}{2}$" pipe 4' high

Total weight on = [(3×37.6992)+(6×4)] × 2.68 = 370#

Total weight on wall = (4×4553)+(4×10.9×18)+370 = 19367#

Radius to outside of watch room wall = 8'

Height of watch room = 8' 3" = 8.25'

Radius of lantern room = 4'-2" = 4.1667'

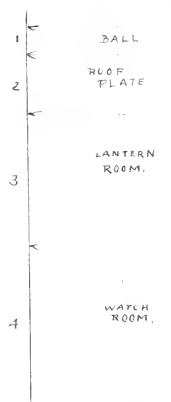
Height from lantern room floor to bottom of plate = 10' $3\frac{1}{2}$" = 10.2917'

Height of roof plate = 2' 6" " = 2.5'

Radius of roof plate at base = 4' 9" = 4.75'

Diameter of ball = 22" = 1.833'

Area of ball under pressure = 190□" = 1.32□'




Wind pressure = 50#/ ft.

Sec I, pressure = 1.32×50 66#

" 2 " = $\frac{1}{2}$ × 4.75 × 2.5

" 3 " = 50×10.2917×4.1667 = 2144#

" 4 " = 50×8.25×6 = 2475#

Moment section I = $66\times(8.25+10.2917+\frac{2.5+1.83}{2})$

= 1450 ft lbs

Moment section 2 =

$247\times(8.25+10.2917+\frac{2.5}{2}) = 5881$ ft lbs

Moment section 3 =

$2144\times(8.25+\frac{10.2917}{2}) = 28730$ ft. lbs

Moment section 4 =

$2475\times\frac{8.25}{2} = 10210$ ft. lbs

Total overturning moment = 1950 + 5881 + 2875 + 10210 = 46271 ft.lbs
Height of center of pressure from line AB = $\frac{46271}{66+297+2144+2475} = 9.288'$

Total

Total pressure = 4982
Total weight tending to prevent over-turning = 19370 + weight of wall

Assume watch room wall 6" thick
Weight of wall = (113.048 − 95.033) × 7.5833 × 150 = 20550 #
Total weight tending to prevent over-turning about section AB = 20550 + 19370 = 39920 #

Point of application of resultant

x = distance of point of application of resultant from center $\frac{x}{4982} = \frac{9.288}{39920}$ ∴ x = 1.16'

Since resultant comes within middle third of base, no reinforcement will be required.

Wind stress on each bracket = $\frac{m}{3r} = \frac{46271}{3 \times 5.2} = 2685$ #

Dead load compression on one bracket = $\frac{39920}{6} = 6650$ #

Total compression on one bracket = 2685 + 6655 = 9340 #
Depth = 6"  Width = $\frac{9340}{6 \times 300} = 5.2''$

$M = \frac{5}{6} dA\, f_s$  $d = 1.5'-18''$ $f_s = 13000$ #

$9340 \times 1.5 \times 12 = \frac{5}{6} \times 18 \times 13000 \times A$

A = 0.862 □"

Use 2 - $\frac{3}{4}$" Round bars for reinforcement in compression.

Watch Room Floor

Weight of steps = $10 - \frac{3}{8} \times 5 \times 23\frac{5}{8} \times \frac{470}{1728} = 120$ #  cast iron
Weight of plates supporting steps (steel) =

$\frac{490}{1728} \times [(11 \times 10\frac{4}{32} \times 4\frac{3}{8} \times \frac{3}{8}) + (167\frac{33}{64} \times 4\frac{3}{8} \times \frac{3}{8})] = 130$ #

Weight of railing =

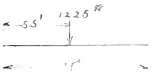
$2 \times 11 \times 10\frac{4}{32} \times 0.7854 \times 1 \times \frac{490}{1728} + (2 \times 167\frac{33}{64} \times .7854 \times 1 \times \frac{490}{1728}) + 4 \times 36 \times .7854 \times 1 \times \frac{490}{1728} = 200$ #

Total weight of stairs = 120 + 135 + 200 = 450 #

Assum[illegible] weight of s[illegible] ac[illegible] cents of [illegible] 6" d[illegible]
Unsupported length = 11'
Weight per foot = $\frac{1}{2} \times 1 \times 1 \times$ [illegible] $+ 100 = 175^{\#}$

Allow $100^{\#}$ load on each step

Watch Room Floor (continued)




Reaction $= \frac{175 \times 11}{2} + 225 + 350 = 1325^{\#}$

M. m x $= [(1325 \times 5.5) - (175 \times 5.5 \times 2.75)] \times 12 = 55704$ in.lbs

$M = \frac{5}{6} d A f_s$

$\frac{3}{4}$" square corrugated bars

A = area of reinforcement per foot

$d = 6 - 2\frac{5}{8} = 3\frac{5}{8} = 3.625''$

$f_s = 13000$

$55704 = \frac{5}{6} \times 3.625 \times 13000 \times A$

$A = 1.419 \square''$ Spacing $= \frac{12.5625}{1.419}$

Area of $\frac{3}{4}'' \times \frac{3}{4}$ bar $= \frac{9}{16} \square'' = 0.5625 \square''$ spacing $= 4\frac{3}{4}$" C. to C.

Number bars per foot $= \frac{1.419}{.5625}$

Walls under Watch-room

Total compress = at bottom of watch room floor =
[illegible] $+ (\frac{1}{2} \times .7854 \times \pi^2 \times 150) + (100 \times .7854 \times 11^2) + 1000$

Total load $= 58010^{\#}$

If wall under watch room floor is 6" thick then radius to C. G of wall $= 4.25'$

Area $= 2 \times 4.25 \times 3.1416 \times \frac{1}{2} \times 144 = 1922 \square''$

Stress per sq. in. $= \frac{58010}{1922} = 30.17^{\#}$

Weight of brackets $= [(\frac{1}{2} \times \frac{5.2}{12} \times 1.5) + (\frac{1}{2} \times 1.5 \times 1.5 \times \frac{5.2}{12})] \times 150 \times 6 = 730^{\#}$

H = depth in feet to which 6" wall is allowable

$\frac{58010 + 730 + (3.1416 \times 8.5 \times .5 \times H \times 150)}{1922} = 300$

$H = \left(300 - \frac{58740}{1922}\right) \times \frac{1922}{3.1416} \times 8.5 \times .5 \times 150$

$H = \frac{517860}{1922} \times \frac{1922}{3.1416 \times 8.5 \times .5 \times 150}$

$H = 58.5'$

Make walls 6" thick to base of tower.

Vertical Reinforcement in wall of tower

Depth 10' between watch room floor

Overturning moment =

$(66 \times 31.9554) + (297 \times 29.7917) + (2144 \times 23.3959) + (2475 \times 14.125) + (4500 \times 5) = 118591$

Total horizontal pressure above joint =

$66 + 297 + 2144 + 2475 + 4500 = 9482$ #

Height of point of application of resultant horizontal pressure above given plane = $\frac{118591}{9482} = 12.5'$

Moment to be resisted by vertical reinforcement is M. $= 118591 \times 12 = 1423000$ in. lbs.

Figure the rods as forming a hollow shell

Then M. $= fZ$ $\qquad z = \frac{.0982\,(d^4 - d_1^4)}{d}$

d = outside diameter $= 8'-8'' = 104''$

$d_1$ = inside diameters =

Then M. $= \frac{18000 \times .0982\,(104^4 - d_1^4)}{104}$

Depth 10'

M. = 1423000 in. lbs.

$d_1 = \left(\frac{18000 \times .0982 \times 104^4 - 1423000}{17}\right)^{1/4} = 103.96$

Use $\frac{1}{2}'' \times \frac{1}{2}''$ rods 6" C. to C.

A = 3.1416 x 103.96 x .04 = 13.1 □"

Depth 20'

Bending moment $= [(9482 \times 22.5) + (10 \times 9 \times 50 \times 5)] = 235845$ ft. lbs.

Total horizontal pressure $= 9482 + 4500 = 14000$ #

Height of Center of Pressure above joint $= \frac{235845}{14000} = 16.9'$

M. $= 235845 \times 12 = 2830140$ in. lbs.

$d = \left(\frac{18000000000 - 2830140}{17}\right)^{1/4}$

d = 103.95"

t = 0.05"

A $= 103.975 \times 3.1416 \times 0.05 = 16.4$ □"

Use $\frac{1}{2}'' \times \frac{1}{2}''$ rods spaced 5" C. to C.

Depth 30'

Bending moment $= (14000 \times 26.4) + 225000 = 399100$ ft. lbs.

Total horizontal pressure $= 18500$ #

Height of Center of pressure above joint $= \frac{399100}{18500} = 21.6'$

M. $= 399100 \times 12 = 4789200$ in. lbs.

$d = \left(\frac{18000000000 - 4789200}{17}\right)^{1/4}$

d = 103.93"

t = 0.07"

A $= 103.965 \times 3.1416 \times .07 = 22.9$ □"

Use $\frac{1}{2}'' \times \frac{1}{2}''$ rods spaced $3\frac{1}{2}$" C. to C.

Depth 40'

Bending moment = $(18500 \times 31.6) + (4500 \times 5) = 607100$ ft. lbs.

Total horizontal pressure = $18500 + 4500 = 23000^{\#}$

Height of C. P. $\frac{607100}{23000} = 26.4'$

Bending moment = $607100 \times 12 = 7285200$ in. lbs.

$d = \left(\frac{1988000000 - 7285200}{17}\right)^{1/4} = 103.89''$

$t = 104.00 - 103.89 = \frac{1}{17}'' = 0.11''$

$A = 103.945 \times 3.1416 \times .11 = 35.94 \square''$

Use $\frac{1}{2}'' \times \frac{1}{2}''$ bands spaced $2\frac{1}{4}$" C. to C.

Reinforcement in tower wall

Depth 50'

Bending moment = $(23000 \times 36.4) + (4 \times 9 \times 50 \times 8) = 851600$ ft. lbs.

Totalhorizontal pressure = $23000 + 1800 = 24800^{\#}$

Height of C. P. = $\frac{851600}{24800} = 34.3'$

Bending moment = $851000 \times 12 = 7819200$ in. lbs.

$d = \left(\frac{1988000000 - 10219200}{17}\right)^{1/4} = 103.85''$

$t = 104 - 103.85 = .15''$

$A = 103.925 \times 3.1416 \times .15 = 49.00 \square''$

Use $1'' \times 1''$ bands $6\frac{5}{8}$" C. to C.

Depth 60'

Total horizontal pressure = $24800^{\#}$

Height of C. P. = 44.3'

Overturning moment = $44.3 \times 24800 = 1098640$ ft. lbs

Moment = $1098640 \times 12 = 13183680$ in. lbs

$d = \left(1988000000 - 13183680\right)^{1/4} = 103.81''$

$t = 104.00 - 103.81 = .19''$

$A = 103.905 \times 3.1416 \times .19 = 62 \square''$

Use $1'' \times 1''$ bands $5\frac{1}{4}$" C. to C.

Depth 65'

Total horizontal pressure $= 24800^{\#}$

Height of C. P. $= 49.3'$

Overturning moment $= 49.3 \times 24800 = 1222640$ ft. lbs.

Moment $= 1222640 \times 12 = 19671680$ in. lbs

$d = \left(1988000000 - 19671680\right)^{1/4} = 103.79''$

$t = 104.00 - 103.79 = \frac{17}{.21}''$

$A = 103.895 \times 3.1416 \times .21 = 68.6 \square''$

Use $1'' \times 1''$ bands $4\frac{3}{4}$" C. to C.

Design of living room roof

Horizontal distance from center of tower to outside end of ridge rib = 12.5'
Horizontal distance of valley rib = 7.00'
Height of end ridge rib from horizontal plane of outer end of valley rib = 9.00'
Distance from outside end of ridge rib to outside end of valley rib = $(9.00^2 + 7.00^2)^{1/2} = 11.42'$
Distance from point where ridge and valley ribs would meet if produced (: e : center of tower in same horizontal plane with ridge rib). to outside end of valley rib = 16.91'
Angle made at center of tower between ridge and valley ribs = $\tan^{-1} \frac{11.42}{12.5} = 42°30'$
Radius of tower = 4.5'
x = difference between total length of valley rib and distance between outside end of valley rib and commencement section

$$\cos 42°30' = \frac{4.5}{x}$$

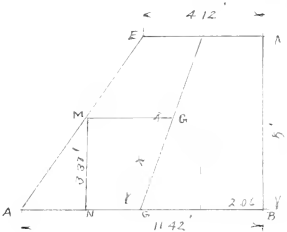
x = 6.1'
Load length valley rib = 16.91 - 6.1 = 10.81'
Distance between inside end of ridge and valley = y

$$\frac{y}{4.5} = \tan 42°30'$$

y = 4.12'
Loaded length of ridge rib = 12.5 - 4.5 = 8.00'
Area of trapezoid = $\frac{11.42 + 4.12}{2} \times 8 = 62.16$ □'

The pitch section of roof is very nearly a trapezoid as shown in the figure.
Center of gravity is in line from BCD at a distance from AB from = to $\frac{h}{3} \cdot \frac{a + 2b}{a + b}$ where

h = CD = $(8^2 + 3.66^2)^{1/2} = 8.8'$




b = EF = 4.12'
a = AB = 11.42'
$\bar{x} = \frac{8.8}{3} \times \frac{11.42 + 8.24}{11.42 + 4.12} = 3.71'$
$GK = \frac{3.71 \times 8}{8.8}$
GK = 3.37'
AE = 10.81'
$\therefore AN = \frac{10.81 \times 3.37}{8.8} = 4.14'$
AN = 7.1'

Then the loads from the sections of roof may be assumed

to at a distance $= 4.14'$ from the wall of the house.
Use We will use a concrete roof 2" thick reinforced with truss-sit reinforcement; will stand a load of 166 #/sq. ft.
2 x area of trapezoid x thickness x weight per foot of concrete and 2 x area of trapezoid x weight per sq. foot of truss sit
Load on each valley beam $= (2 \times 62.16 \times \frac{2}{12} \times 150) + 2 \times 62.16 \times .723 = 3200$ #
Now the effective length of the valley rib [illegible]

But the length of that projection as scaled from the drawing $= 10'$
Let $\theta = \angle$ valley rib makes with horizontal

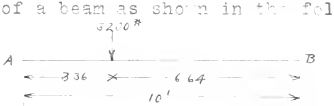
Then $\tan\theta = \frac{9}{12.5} = 0.7200$

$\theta = 35^\circ 50'$

x = horizontal distance of point of load from outside wall

$x = \cos 35^\circ 50' \times 4.14$
$x = 3.36'$

THEN we have the equivalent of a beam as shown in the following figure




$R_A = \frac{3200 \times 6.64}{10} = 2125$ # in. lbs.
M max $= 2125 \times 3.36 \times 12 = 85680$ in. lbs.
M = fz use 6" $12\frac{1}{9}$# I beam

$85680 = 16000\,Z$ .:Z = 5.36

Use a $3'' - 5\frac{1}{2}$# I beam in ridge for stiffening.

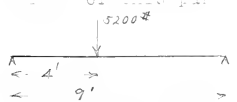
Design of floor above living room
assume the greatest stress to come on a beam located 3' from outside wall as shown in the figure
Length = 11.5' Live Load = 200 #/□'
Assume floor 6" thick
Then dead load = 75#/sq? ft. Total = 275 #/□'
Bending moment $= \frac{275 \times 11.5 \times 11.5}{8} = [illegible] \times 100$ in. lbs. per ft.
Using I" rods 2" from bottom
$M = \frac{5}{6} d A f_s$ d = 3.50 " , $f_s$ = 16000
.; $109100 = \frac{5 \times 3.50 \times 16000}{6} A$

$A = \frac{6 \times 109100}{5 \times 3.50 \times 16000} = 2.31$ per sq. in. = 9.34 rods per foot

Center of pressure of flood water on I beam 4' from wall, width of floor $= \frac{4.5 + 1.}{2} \times 5' \times .5 \times 150 = 3000\#$

Center of gravity of triangle outside of point 4 from wall is centroid concentrated is 2.3' along beam from other point of support

$W$ load of this part $= \frac{10.50+14}{2} \times 3.75 \times .5 \times 150 = 3445\#$




Then we have a beam thus;

$M\ max = [5200 \times \frac{9}{4} \times 4 - 3445(4-2.3)] \times 12 = 68400$ in.lbs.

$f = I6000\#$ $M = fZ$ $Z$ in $\frac{3}{4}$ I beam

$\therefore Z = \frac{68400}{16000} = 4.27$

Design of Turbine.

Total pressure from wind above dividing plane $= 24000\#$
Height of its C.P. above surface $= 40.5 + 20 = 30.5'$
Total load above dividing plane $= 20 \times 12 \times 20 = 30480\#$
Height of C.P. above surface $= 30.5'$
The highest available head on the gate is 40 feet above the surface of still water and the lowest pressure corresponds to 2000#/sq. ft.; the total load on the gate above the dividing plane is

When shrouded the theoretical pressure is 50 lbs. per sq. ft.

Then pressure from wind below dividing plane $= 50 \times 20 \times 12 = 12000\#$
Height of C.P. above surface of still water $= 13.5'$
Pressure from overhanging water $= 15 \times 10 \times 20 \times \frac{1}{2} = 1500\#$
Height of C.P. above surface $= 7.5'$
Total height of C.P. above surface $= \frac{24000 \times 30.5 + 12000 \times 13.5 + 1500 \times 7.5}{24000 + 12000 + 1500} = 24.67'$

Total $W$ of turbine $= I. + 80 = 58010 + \{[3.1416 \times (\frac{12}{12})^2 \times 8 \times .4916 \times \pi] \times 8.25 \times 150 + [(.7854 \times 9^2 - .7854 \times 8^2) \times 6.5 \times 150] + [\frac{18.6^2}{12^2} \times .7854 - .7854 \times 6\frac{1}{2}^2] \times 65 \times 470] + 8.7[$
$[2.75 + 18 \times \frac{1}{48} \times 3.33 \times 470] + (47 \times \frac{13}{12} \times \frac{1}{48} \times 3.67 \times 470) + (6 \times 3200) + (6 \times 12.25 \times 10.81) +$
$+ (6 \times 5.5 \times 8) + [(\frac{13.1}{144} \times 16) + (\frac{16.4}{144} \times 16) + (\frac{22.9}{144} \times 16) + (\frac{35.49}{144} \times 16) + (\frac{49}{144} \times 16) + (\frac{62}{144} \times 16) + (\frac{68.6}{144} \times 5^2)$

Total [illegible] E.L. + 20 = 377I[illegible]#
Weight [illegible] of [illegible] E.L. + 20 = 6 X [illegible] X [illegible] X I X

I50 = 226[illegible]00#

Area of [illegible] = I5I[illegible] /sq. ft.
Total weight above datum = 377I50 + (20 X 226[illegible]00) = 4,9I[illegible]50
Cu. ft. of water displaced = $\frac{I5I[illegible]}{2}$ X I5 = II[illegible]40 cu.ft.

[illegible] water displaced = [illegible] X II340 = 70[illegible]750 #
Effective weight tending to resist overturning = [illegible] )
- 70[illegible]750 = 4,20[illegible]800#
Total horizontal [illegible] = I,50[illegible]#
Height of C. P? = 9.0[illegible]'
Let x = distance from axis of [illegible] resultant [illegible]

[illegible] $\frac{I[illegible]}{4[illegible]}$ = $\frac{x}{9.[illegible]}$

.: x = [illegible].5

Then [illegible] 1/2 [illegible]
L[illegible] W. = [illegible] resultant [illegible]
[illegible]
Then x = 5'

[illegible] = I[illegible]
W = [illegible]

[illegible] C. P.
.: $\frac{I[illegible]}{W}$ = [illegible]

W = [illegible]
C[illegible]

[illegible] - [illegible] = [illegible] cu. ft.
[illegible]0

[illegible]
[illegible]0

[illegible] : E.L. - 20'
D[illegible] = [illegible]'
[illegible] E. L. O. [illegible]
+(1[illegible] X [illegible] X $\frac{2I}{2}$ X [illegible]) = [illegible]+ [illegible]#

[illegible] C.P. [illegible]

-[illegible] = [illegible] XI[illegible] + [illegible] = I[illegible]
114600

If th [illegible] (-25) is 491350+(25X1512X150)=
10583150

[illegible] EL. - [illegible] = I[illegible] I[illegible] - I0[illegible] I[illegible] = [illegible]I00[illegible]
H = [illegible]
Th n:II[illegible] H X 150 = [illegible] I00[illegible]
H = I[illegible]0'to[illegible] m ch

If [illegible] I[illegible]' [illegible] ll [illegible] - [illegible]' [illegible]
Th n : [(3.1416X6X6)+116]150XH = 2810026

.; H = [illegible]I0[illegible] / 2I[illegible] X I50 = [illegible]'

3 - [illegible]' [illegible]ells [illegible] I2' [illegible]ll
.: (II[illegible] + 3X [illegible] X [illegible])I[illegible]0 X H = [illegible] I00[illegible]
H = [illegible]2'

[illegible] - 3' [illegible]lls [illegible] I - I[illegible]' [illegible]

Workin[illegible] Ch[illegible]

P[illegible] = 20 x [illegible] =
=I[illegible]00#
P[illegible] = (I[illegible]+ [illegible] X I[illegible]) = I[illegible]# s[illegible].ft.
Av[illegible] = I[illegible]0 + I / 2 = I[illegible] /sq.ft. [illegible]

$\frac{d}{p} = \frac{I - \sin}{I + \sin}$

Ass[illegible] 0 = 20° f[illegible] soft fill[illegible]
Horizont l press[illegible] sq. ft. = I - .[illegible] / I + .[illegible] X I[illegible] = [illegible] /sq. ft.
T[illegible] = 24 X [illegible] X [illegible]0 = [illegible]#

[illegible] pe[illegible] v[illegible] = [illegible]0 x I2 X I[illegible] = I[illegible]

[illegible] , f = [illegible]00#/sq. i[illegible].

Z = I / [illegible] [illegible] = I[illegible]" [illegible] = f[illegible] .: [illegible] / [illegible] XI[illegible]²

d = √(6 X 198720 / 800 X 12) = II"

[illegible] - [illegible]" - [illegible]" X I [illegible]" [illegible]

Working Chamber Bracing.

Stress = P = 40000# on each rang[illegible]

S= area of cross section

f = safe compression stress of pin = [illegible]# sq.in. for [illegible] pin

l = length = 12' = 1[illegible]"

h = smallest dimension of piece

$$\frac{P}{S} = f - \frac{f}{100} \times \frac{l}{h}$$

[illegible] 7" X 10"

Stress on each rang[illegible] = 40[illegible]#

Then $\frac{40000}{S}$ = 70[illegible] - $\frac{7 \times 1[illegible]}{[illegible]}$ = [illegible]

S = 70 sq. in. [illegible]

Area of [illegible] " X 1[illegible]" piece = [illegible]0sq. in.

Use [illegible] " X 10 " pin for [illegible]

Stress [illegible] radial bracing = [illegible]

Try [illegible] 10" 10" pin [illegible].

$\frac{[illegible]}{S}$ = 700 - $\frac{7 \times 12 \times 1[illegible]}{10}$ = S = [illegible]

10" X 10" [illegible].

[illegible] of [illegible] l = [illegible]" = [illegible]"

Try [illegible] 7" X 10"

$\frac{[illegible]}{S}$ = [illegible]00 - $\frac{7 \times [illegible] \times 12}{[illegible]}$

S = 77 sq. in. [illegible]

Area of piece = [illegible]0/s .in.

Ceiling of Working Chamber of [illegible]

[illegible] X 20 ( [illegible] X $\frac{2[illegible]}{2}$ X 2[illegible] $\frac{1}{12}$ )=

= 2077500#

We shall [illegible] I - [illegible] in diameter [illegible] each [illegible]

The lock shafts will be $\frac{1}{2}$"st[illegible] plate

The [illegible] of st[illegible] 12 n lock will be ( 4 X 2[illegible] X [illegible] X

I $\frac{11}{12}$ X I $\frac{11}{1}$ ) 400 = [illegible]#

[illegible] of [illegible] = 2077500 - [illegible]# = [illegible]#

[illegible] = ( [illegible] X $\frac{2[illegible]}{2}$ X 20 - 50.[illegible])

X 150 = [illegible]

D[illegible] of [illegible] = $\frac{2077500}{[illegible]}$ = [illegible]

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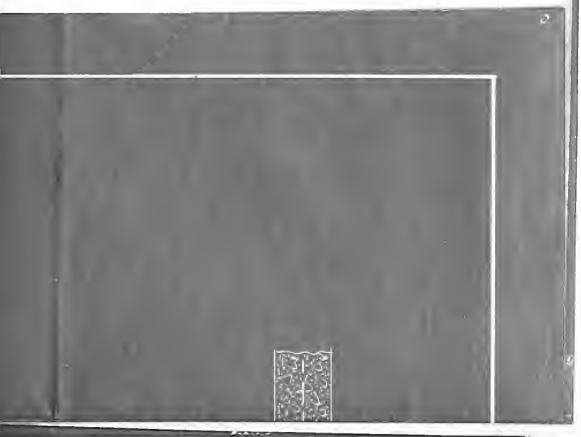

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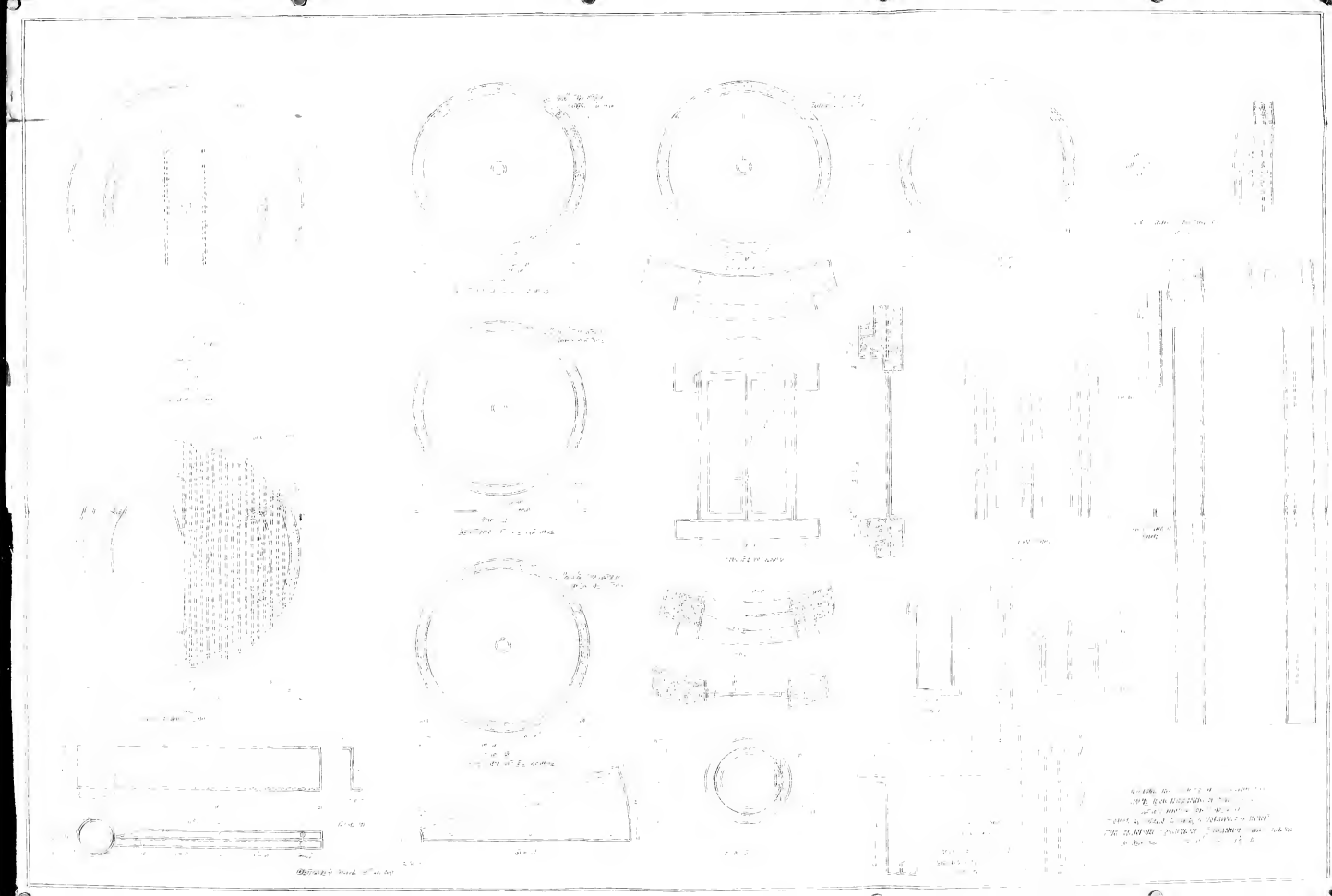

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DETAILS OF
LIVING HOUSE.
ETE HARBOR LIGHT-HOUSE
PLAN 1/4"=1' ELEVATION 1/8"=1'

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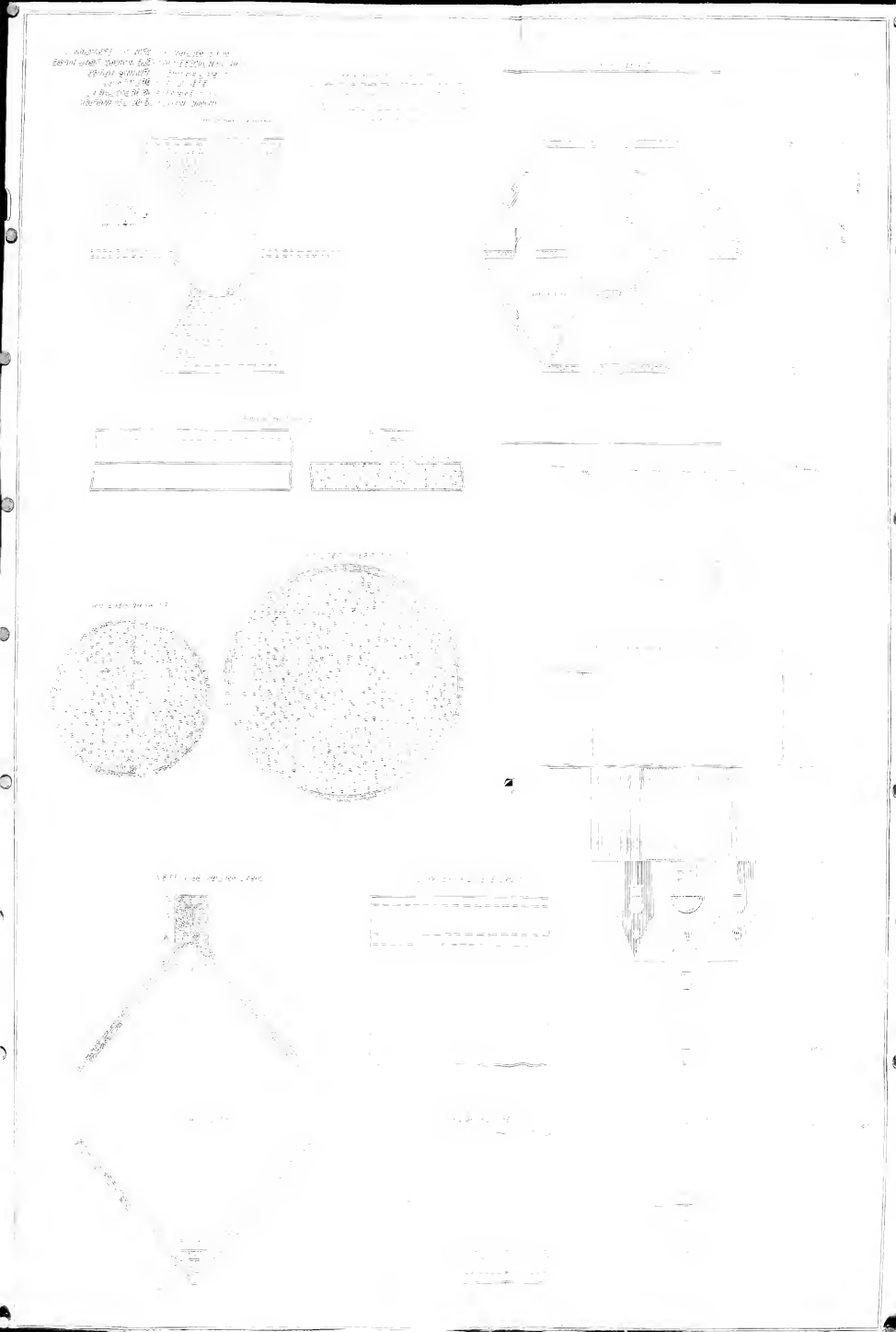

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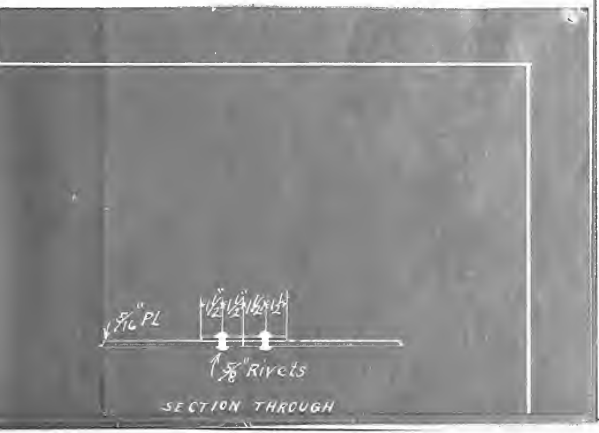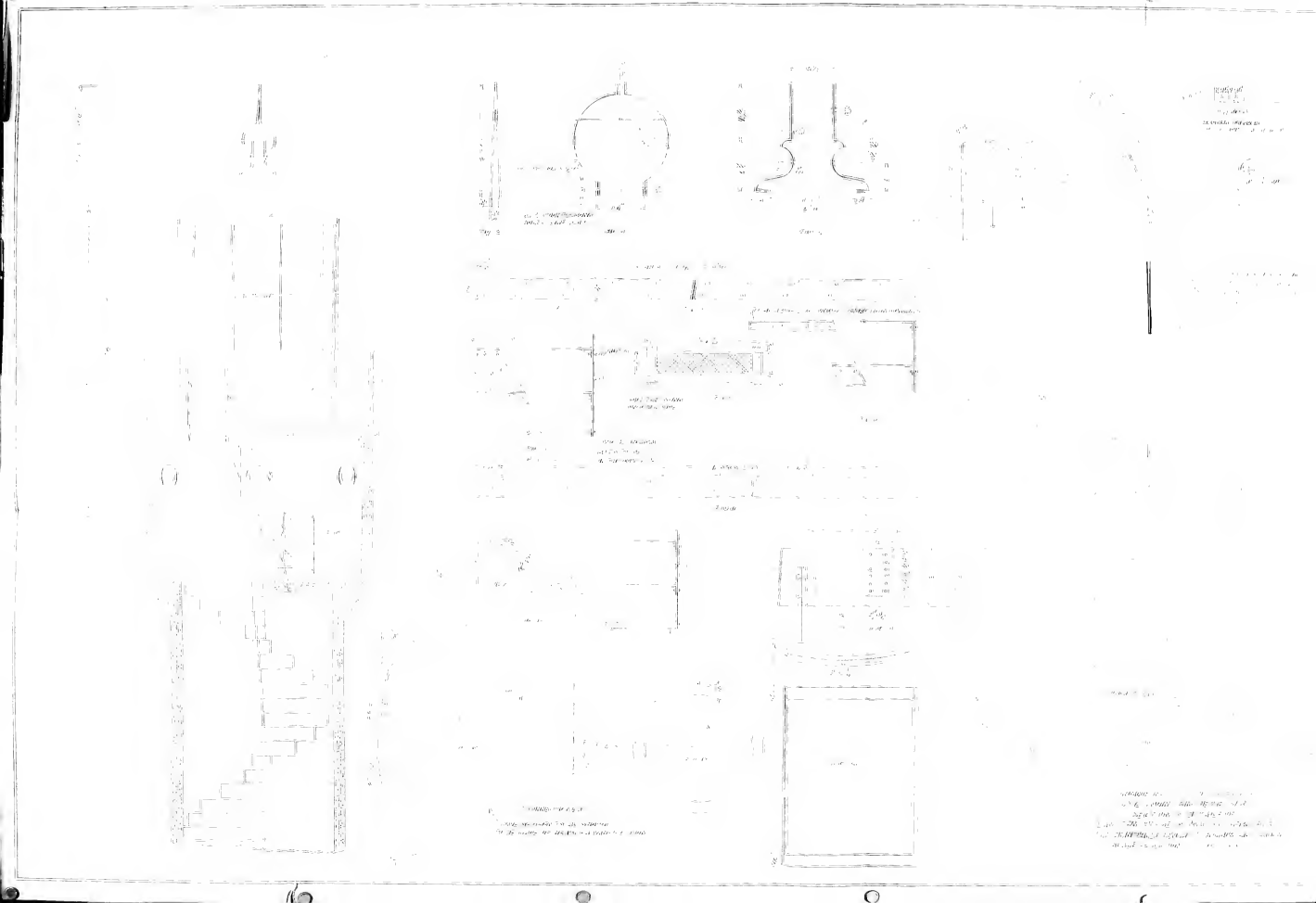
5/16" PL
5/8" Rivets
SECTION THROUGH